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硕 士 学 位 论 文

计算机化心电图自动分析中的基线漂移滤除与QRS波群检测

Research on Baseline Wander Removal and QRS Detection in Automated Analysis of Computerized Electrocardiogram

杨开涛

指导教师：李绍滋　　吕艳萍

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摘　要

目前，计算机化心电图自动分析是一个热门的研究领域。它正在使心电仪器变得越来越智能，从而带来了心脏疾病诊断、监护、防控等方面的变革。但是这一领域的进一步发展正受到两个方面因素的制约：⑴心电图在采集的过程中通常会受到各种噪声的干扰；⑵缺少可靠的、稳定的算法来准确检测出心电图上的各个特征点。

因此，本文将围绕两个问题展开研究：⑴滤除心电图信号中最普遍的一种噪声——基线漂移；⑵检测心电图信号中最显著的成分波——QRS波群。这两项研究是心电图自动分析技术中最重要的工作。本文的主要研究工作及创新点归纳如下：

1、提出了基于离散余弦变换的算法以滤除心电图信号中的基线漂移。基线漂移是心电图信号中最常见的一种噪声，几乎存在于每一条心电图记录中。基线漂移会影响人们对心电图信号低频成分波的观察和测量，而这些低频成分波通常包含了丰富的医疗信息。比如心电图中的ST段是反映心肌梗塞病理最重要的特征段，但它很容易受到基线漂移的影响。滤除基线漂移的难点在于它在频域上通常与心电图信号的低频成分波相重叠，滤除基线漂移可能会引起这些低频成分波的失真。为解决这一问题，本文提出了一个基于离散余弦变换（DCT）的双向自适应滤波方法。它能够最大限度地滤除基线漂移，同时又尽可能地不对心电图的低频成分波构成失真。保证本文算法性能的原因有以下两点：⑴本文算法中的DCT滤波方法具有理想的频率特性，能够精确地滤除频带上多余的频率成分，而对其它频率成分不构成影响；⑵本文提出的双向自适应机制能够使滤波器的截止频率自适应地调整，使它同时适应于心跳基本频率和基线漂移的严重程度。

2、提出了基于sigmoid非线性变换的算法以检测心电图信号中的QRS波群。QRS波群是心电图信号中最显著的成分波，它不仅包含了丰富医疗信息，而且是检

测其它成分波的参考坐标。在检测P波和T波的时候，首先需要检测出QRS波群，然后以它为参考，在它周围检测出P波和T波。但是检测QRS波群的难点在于各种噪声的干扰、高幅值P波T波引起的误检、和QRS波群自身在形态上的多样性。本文提出了一个基于sigmoid函数和DCT滤波的算法。该算法能够有效抑制各种干扰，减小各种形态QRS波群之间的幅值差异，从而保证了算法较高的准确率。

总之，本文的研究内容是心电图自动分析技术中亟须解决的两个问题——基线漂移滤除与QRS波群检测。这两个问题是任何心电图自动分析技术都无法避免的，但它们各自都具有挑战性。针对这些挑战，本文都提出了相应的算法。本文算法通过了真实和模拟心电图信号的测试，而且与文献中几个经典的算法进行了对比。大量的实验结果都显示了本文算法的实用性和可靠性。本文的工作将为心电图自动分析的后续研究做一个良好的铺垫。

关键词：计算机化心电图； 基线漂移滤除； QRS波群检测

Abstract

Currently, automated analysis of computerized electrocardiogram (ECG) is an active area of research. It is making the ECG equipments more and more intelligent, therefore evoking revolution in different aspects including cardiac disease diagnosis, cardiac disease monitoring, cardiac disease prevention and control, etc. However, the further development of this area is being restricted by two factors: ECG is usually contaminated with a variety of noises and artifacts during acquisition; the lack of reliable and stable algorithms to accurately detect the ECG characteristic points.

To this end, this study will focus on two main tasks: filtering out the most typical noise in ECG signals, namely the baseline wander; detecting the most significant wave components, namely QRS complexes. Both of them are the most important work for automated ECG analysis. The main contribution and innovative points of this study can be summarized as below.

Firstly, a algorithm based on Discrete Cosine Transform (DCT) is proposed to remove baseline wander from ECG. Baseline wander is the most typical noise in the ECG signal, which exists in almost every ECG record. It affects the observation and measurement of some low-frequency ECG components which usually contain a wealth of medical information. Take the ST segment for example, which is the key segment for diagnosing myocardial infarction, however it is vulnerable to be effected by baseline wander. The difficulty of baseline wander removal lies in the fact that it is usually overlapped with low-frequency ECG components in the frequency domain, therefore eliminating it may cause distortion to low-frequency ECG components. To solve this problem, a dual adaptive filtering method based on DCT is proposed in this thesis. It can

maximize the elimination of baseline wander, meanwhile minimizing the distortions induced to low-frequency ECG components. Two factors guarantee the high performance of the proposed algorithm: the proposed DCT filtering method has ideal frequency characteristics which contribute to the accurate filtering out unwanted frequency components without affecting the others; the proposed dual adaptive mechanism can adaptively adjust the filter's cutoff frequency in accordance with both the cardiac fundamental frequency and the severity of baseline wander.

Secondly, a algorithm based on sigmoid nonlinear transform is proposed to detect QRS complexes in ECG. QRS complexes are the most significant components of ECG signals, which not only contain valuable medical information, but also play an inportant role when detecting other waves (e.g. P waves and T waves). In the detection of P wave and T wave, it is necessary to detect the QRS complex at first, then the P wave and T wave are to be located abuts the QRS complex. QRS complex detection is a challenge task due to the interference of different noises, the false alarms caused by high-amplitude T waves and P waves, and the QRS complex diversity in morphology. This thesis presents an algorithm based on the sigmoid function and DCT filtering, which can effectively suppress various types of interferences, reduce the magnitude difference between diverse QRS complexes, thus ensuring a higher accuracy for QRS complex detection.

In summation, this study focus on two urgent issues in automated ECG analysis, namely baseline wander removal and QRS detection, which can not be avoided by any automated ECG analysis techniques. However, both of them have their own challenges. Corresponding algorithms have been proposed to solve these issues. The proposed algorithms are tested with real and simulated ECG

signals, and compared with several classic algorithms in the literature. A large number of experimental results have shown the usefulness and reliability of the proposed algorithms. The finished work of this study will lay the groundwork for the follow-up research of automated ECG analysis.

Keywords: Computerized Electrocardiogram; Baseline Wander Removal; QRS Detection

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